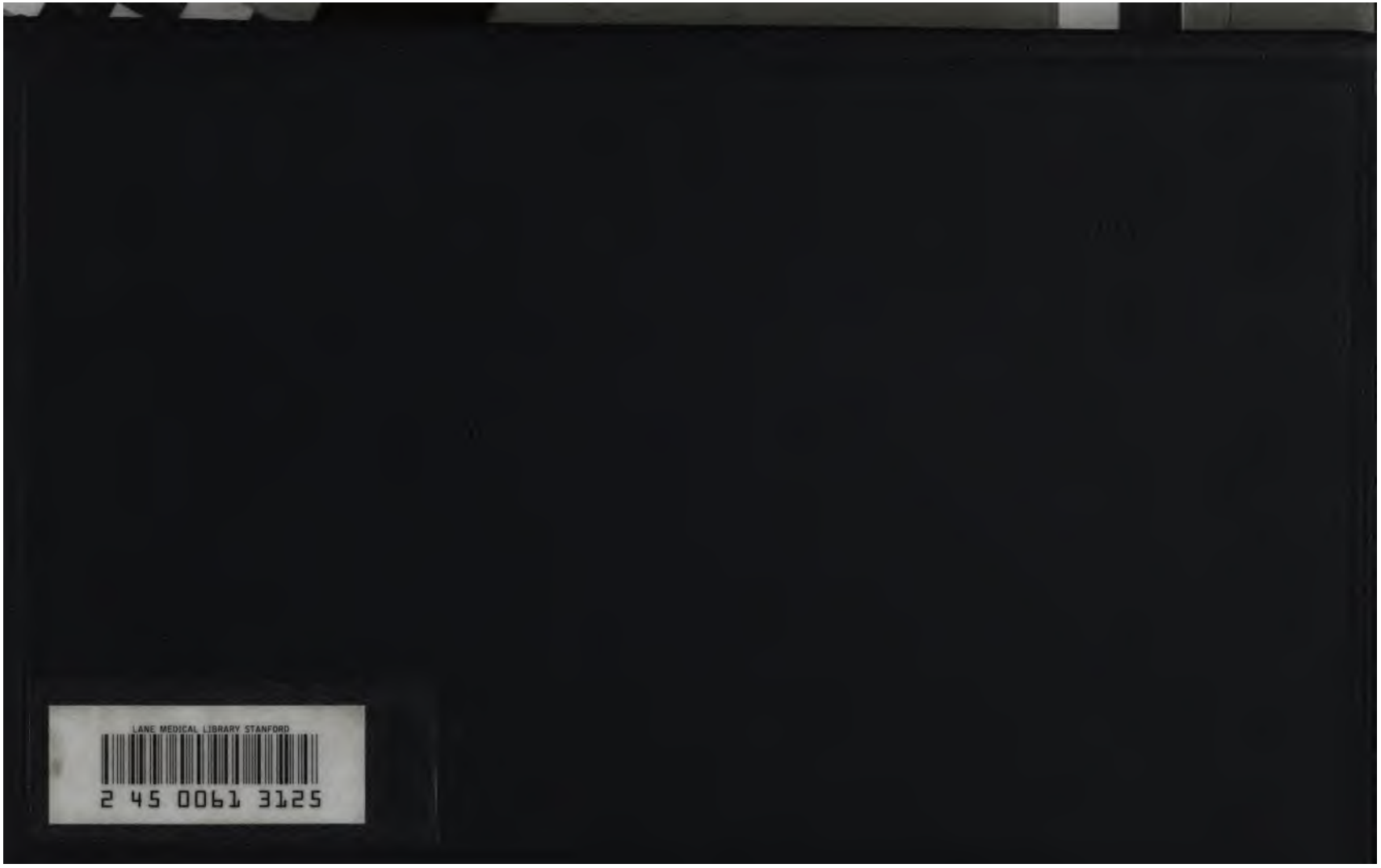

SURGICAL ANATOMY OF THE TEMPORAL BONE

SOME POINTS IN THE SURGICAL ANATOMY OF THE TEMPORAL BONE

FROM BIRTH TO ADULT LIFE

BY

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PREFACE

THESE Hunterian Lectures were delivered at the Royal College of Surgeons in 1906. The 500 specimens which were then shown, and upon which the Lectures were based, can be examined by any one interested in the subject.

ARTHUR H. CHEATLE.

18 SAVILE ROW, 1907.

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LECTURE I

A. THE TEMPORAL BONE AT BIRTH

THE temporal bone at birth is situated at the side and base of the skull with the membrana tympani lying in a nearly horizontal plane and flush with the surface, there being no bony meatus.

(1) THE BONE AS A WHOLE

The bone is made up of three portions which are easily separable.

The squamo-zygomatic or squama.
The tympanic ring.
The petrous, which contains the labyrinth.

FIG. 1.—AT BIRTH.
Right bone, outer aspect. Membrane and ossicles removed.

FIG. 2.—AT BIRTH
Left bone, outer aspect. Membrane removed. Ossicles in position.

(i) *The outer aspect* is gently convex from above downwards and shows the squamo-zygomatic portion with the attached tympanic ring and part of the petrous. Below the line of the zygomatic process which marks more or less accurately the floor of the middle fossa and therefore the roof of the middle ear and antrum, two roughly triangular processes descend; the anterior forms part of the glenoid fossa externally and part of the floor of the middle fossa internally, its anterior edge being continuous with the upper part of the squama, and its posterior edge forming the upper edge of the Glaserian fissure.

The posterior triangular process, the more important from an otological standpoint, forms at its upper part the outer wall of the attic or upper part of the middle ear in front, and the outer wall of the antrum behind,—both walls being therefore continuous. After forming these walls it descends, having a slight twist which makes its surfaces anterior and posterior, and narrowing to an apex extends as low as the stylo-mastoid foramen. This descending part lies against a free descending surface of the petrous below the antrum, and has the upper part of the posterior limb of the tympanic ring lying on its anterior surface. The inner border is free and projects into the back part of the middle ear; the outer border together with the continuous posterior border of the upper part which forms the outer wall of the antrum, articulates with and overlaps the adjacent free

surface of the petrous forming the masto-squamosal suture.

The two extremities of the tympanic ring are attached to the front of the upper part of the anterior free border of the posterior triangular process with an interval between them. The plate of bone between the extremities up to the level of the zygoma forms the outer wall of the attic, in which lie the head of the malleus and body and posterior process of the incus. It will be noticed that this outer attic wall not only overhangs the uppermost part of the middle ear but also the posterior superior part, as it has a slope downwards and backwards. Just below the extremity of the anterior limb of the ring a small plate of bone projects backwards and inwards from it having a free border above against which rests the neck of the malleus. This little projection can be seen all through life and frequently requires removal, when performing the radical operation, in order thoroughly to expose and clear a cell or recess anterior to the head of the malleus and above the canal for the tensor tympani. The ring joins below with the projecting floor of the middle ear formed by the petrous; while in front and below it forms the outer boundary of the Eustachian tube; and in front and above, the lower boundary of the Glaserian fissure.

Across the ring is stretched the membrana tympani with the handle of the malleus embedded

in it, forming together with the outer attic wall the outer boundary of the middle ear.

Behind and below the masto-squamosal suture is a smooth surface of bone formed by the petrous; dense in front and below where it forms the mastoid mass from which the process is subsequently developed, thinning out behind where it is grooved internally by the lateral sinus. In this smooth part of the petrous, at its anterior inferior aspect, is the stylo-mastoid foramen occupying such a superficial position that the facial nerve is in some danger during operation; later in life the foramen appears at the inferior surface and the bone immediately behind it becomes the digastric fossa.

Before birth, at the posterior and upper aspect of this smooth petrous portion behind the antrum, is an irregular depression occupied by a mass of cartilage to which vessels pass from the fossa under the superior semicircular canal. This cartilage is usually ossified at birth, but an irregular opening and the vessel track remain for some time running inwards behind the antrum.

The portion of the petrous seen below and in front of the tympanic ring is the outer wall of the canal for the internal carotid artery.

(ii) *The inner aspect* shows the upper vertical cranial part of the squamous and the superior and posterior surfaces of the petrous with a border between them. The petrous slants inwards and forwards, an important point to remember when operating.

FIG. 3.—AT BIRTH.
Right bone, inner aspect.

FIG. 4.—AT BIRTH
Left bone, inner aspect.

(*a*) The superior surface, which points somewhat forwards and outwards, has externally the petro-squamosal suture, or rather the thin edge of the overlapping tegmen from the petrous, running from before backwards and forming with the underlying projection from the squama the roof common to the Eustachian tube and attic in front and the antrum behind. Under the free edge of the tegmen is lodged a process of dura mater and sometimes the remains of the petro-squamosal sinus. The petro-squamosal sinus receives veins, having a meningeal covering, from the middle ear below and from the meninges and temporo-sphenoidal lobe above. There is therefore, in early infancy especially, a direct communication between the middle ear tract and the meninges, accounting for the frequency of meningitis secondary to middle ear infection. This roof of the attic and antrum is extremely thin and

translucent, remaining so, with rare exceptions, all through life. If it be examined from below the under projecting free border of the squama forms a very distinct ridge running from before backwards, dividing the roof into an external and an internal part. The ridge is frequently seen in operating and requires removal in order to clean and examine the inner part thoroughly. Internal to the roof of the attic is the hiatus Fallopii in which the facial nerve lies against the dura mater; infection may pass from the middle ear to the middle fossa by this route. Behind the hiatus is the anterior crus of the superior semicircular canal, while internal to the hiatus is smooth, compact bone covering the cochlea in front and a mass of diploetic bone internally.

(*b*) The border between the two surfaces is interrupted in the middle by the superior semicircular canal. The bone smooths off externally on the same level as the roof of the antrum and middle ear, but internally there is a drop and under the curve of the canal is a deep fossa leading to the canal which carries vessels and a process of dura mater to the mass of cartilage already alluded to. This canal becomes obliterated as a rule, but a connection with the antrum has been described and infection may pass by it from that cavity to the posterior fossa. The border gives attachment to the tentorium and has running along it, but not grooving it at this age, the

superior petrosal sinus which runs from the cavernous to the lateral sinus.

(*c*) The posterior surface is wholly formed by the petrous and shows externally the shallow groove for the lateral sinus lying below the level of the antrum and separated from it by dense cancellous bone, thus accounting for the rarity of lateral sinus infection in infancy. Internal to the groove, in a horizontal line with the internal auditory meatus, midway between the upper and lower borders of the surface, the upper crus of the posterior semicircular canal is plainly outlined, becoming buried as it curves downwards. Below it is the aqueductus vestibuli. Through the aqueduct passes a process from the membranous labyrinth to a closed sac, the saccus endolymphaticus, which lies on the bone below and external to the aqueduct. Infection occasionally passes by this route from the middle ear *viâ* the labyrinth to the saccus or posterior fossa. From the inner extremity of the posterior canal the superior can be seen commencing its course upwards and forwards. Internal to the canals is the internal auditory meatus running outwards for the passage of the facial and auditory nerves, the facial lying anteriorly and superiorly. The outer end of the meatus is also the inner wall of the labyrinthine vestibule, it is thin and perforated for the passage of the vestibular and ampullary branches of the auditory nerve. The anterior wall of the meatus forms the base of the

cochlea and is perforated for the cochlear branch of the auditory nerve. In the upper corner between the outer and anterior walls is the large foramen for the facial nerve; the falciform process runs horizontally below it and separates the facial

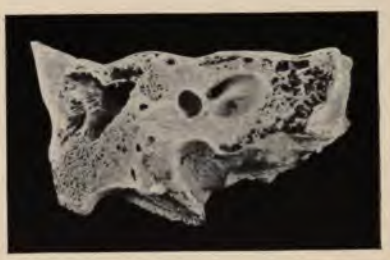

FIG. 5.—INFANT.

Left bone. Section through antrum, external semicircular canal, vestibule, and internal auditory meatus.

from the auditory. Infection may pass from the middle ear through the vestibule by direct extension of caries or through the auditory nerve-sheaths to the posterior fossa.

(iii) The inferior aspect shows posteriorly and externally a raised, smooth surface for articulation with the occipital bone, external to which is the cartilaginous styloid process represented by a foramen in the dry bone. Anterior and internal to these is a smooth, shallow groove occupying the whole width of the surface, the sulcus jugularis, against which lies the jugular bulb. Externally the sulcus forms the thin perforated floor of the middle ear; through this floor the bulb may become infected; it is curious, how-

ever, considering the anatomy of the parts, how rare is this complication of middle ear suppuration. Internally and posteriorly the sulcus covers the inferior surface of the inferior crus of the posterior semicircular canal as it opens into the floor of the vestibule. Internally and anteriorly it lies against the inferior surface of the first turn of the cochlea. In front of and internal to the sulcus where it forms the middle ear floor is the external opening of the internal carotid canal. Just anterior to the inner part of the sulcus is the aqueductus cochleæ through which the perilymph in the cochlea communicates with the subarachnoid space, forming a pathway for infection in labyrinthine suppuration. Internal to the aqueduct the bone joins with the occipital. The border between the inner and outer junctions with the occipital forms an upper boundary of the jugular foramen.

(iv) *The apex* shows externally and superiorly a wide opening common to the Eustachian tube

FIG. 6.—AT BIRTH.
Left bone. Apex.

below and externally, and the canal for the tensor tympani above and internally, a separating shelf of thin bone projecting from the inner wall. Below and internal to this common opening is the internal aperture for the internal carotid artery.

(2) THE MIDDLE EAR TRACT

(i) *The antrum and attic from above.*—If the roof common to the Eustachian tube, attic and antrum be removed, the head of the malleus and body and posterior process of the incus will be exposed lying in the attic with the Eustachian

FIG. 7.—INFANT.
Right bone. The roof of the middle ear tract removed.

tube in front of them. The cavity of the antrum will be seen behind the incus, and it can be appreciated that the cavity has an outer wall formed by the squama, an inner wall abutting against the semicircular canals, and a posterior wall separating the cavity from the posterior fossa, both the inner and posterior walls being formed by the petrous.

All the walls unite below to form the apex. The opening of the antrum into the attic is above and in front immediately behind the incus.

(ii) *The squamo-zygomatic and tympanic ring separated from the petrous.*

FIG. 8.—AT BIRTH.

Right bone. The squamo-zygomatic portion and tympanic ring separated from the petrous portion.

If the squamo-zygomatic portion with the attached tympanic ring and membrane be removed, the inner walls of the antrum and middle ear lie exposed.

(*a*) *The inner walls of the middle ear tract.*—It is at once seen that the antrum and middle ear are laid down as one continuous cavity, and so they remain all through life. I have never seen the

antrum absent except in cases of congenital malformation.

The lining membrane is continuous with that of the Eustachian tube and, therefore, with that of the nasopharynx. Pockets and folds exist round the contained structures.

It is hardly to be expected that infection spreading up the tube should be limited to the middle ear proper without involvement of the antrum, and my experience, obtained by dissection of specimens, leads me more and more to think that in cases of acute suppuration the antrum is always simultaneously affected, the progress of the case depending on the amount of drainage and the virulence of the infection.

The name "mastoid antrum" is confusing, for it implies that the cavity is developed as a mastoid cell; in reality it is part of the middle ear, and laid down as such in fœtal life long before the mastoid cells appear. The word "tympanic" is, therefore, more applicable.

FIG. 9.—SIXTH MONTH OF FŒTAL LIFE.

Left bone. Squamo-zygomatic portion separated from the rest of the bone, showing antrum, ossicles and membrane in position.

FIG. 10.—EIGHTH MONTH OF FŒTAL LIFE.

Right bone. Squamo-zygomatic portion, tympanic ring, and ossicles separated from petrous, and turned round.

Anatomists used to divide the temporal bone by an imaginary line which necessitated the description of the antrum entirely apart from that of the middle ear, and was the cause of much confusion.

On examining the exposed tract it is first seen that it does not extend right out to the posterior border of the petrous. The antrum is roughly triangular in outline; it is situated above and behind the roughly circular middle ear proper, the walls of which meet anteriorly to form the opening common to the Eustachian tube and tensor tympani canal. The projecting roof or tegmen is common to the antrum, attic, and tube, and runs downwards, forwards, and inwards. The

lower and posterior outlines of the antrum are formed by a free border of the petrous and are flush with the outer surface, but there is usually a dip, of varying extent, internally. The floor of the middle ear which is often lined with cells, is formed by the thin projecting plate of bone from the petrous; it curves upwards at each end, anteriorly as far as the Eustachian orifice and posteriorly to about the level of the base of the pyramid, ending as a border which externally lies against the apex of the posterior descending triangular process of the squama and internally is free, frequently forming a pocket or recess outside the pyramid on the posterior wall of the middle ear.

The inner wall of these cavities is composed of the outer parts of the bony labyrinth with the facial nerve running over them. At the junction of the antrum with the middle ear the anterior limb of the external semicircular canal comes to the surface as a smooth, hard, white mass of bone, and forms the inner boundary of the opening of the antrum into the attic; but it is not so thick as it appears and is easily wounded. This structure is of great importance as it is not only a guide when laying the antrum into the middle ear while performing the radical operation, but it also shows the way in operations on the semicircular canals and vestibule, and is one of the parts of the labyrinth most frequently attacked by disease. It has attached to it, in front and below, the thin Fallopian canal.

The facial nerve enters the middle ear attached to the external canal at the top and in the centre of the inner middle ear wall, on the same level as the canal for the tensor tympani which runs right up to it, and on a vertical level with the anterior edge of the oval window over which it passes. After passing over the top of the sinus tympani, it leaves the external canal at the apex of the opening into the antrum and runs down the posterior middle ear wall with a slight inclination outwards, to emerge at the stylo-mastoid foramen.

The Fallopian canal may be incomplete, usually in the arching part, and may remain so all through life, leaving the nerve in contact with mucous membrane and therefore liable to involvement during inflammation of the middle ear.

The oval window lodges the base of the stapes; it points backwards, inwards and upwards into the vestibule of the labyrinth. Below and anterior to the oval window is the promontory, which is really the outer wall of the beginning of the first turn of the cochlea; this also is not so thick as it appears. Further forwards the hard promontory smooths off into the thin wall of the internal carotid canal. Below and behind the promontory is the round window which leads to the cochlea.

The inner wall of the antrum behind and above the anterior limb of the external canal is smooth or slightly cellular, and is formed of cancellous bone which separates the cavity in an inward and forward direction from the upper limb of the

superior canal and the fossa under it; lower down the external canal becomes buried in cancellous bone to meet the posterior canal. This inner wall curves round somewhat, external to the posterior semicircular canal, forming a *posterior wall* to the antrum, which is roughly triangular in outline and formed by a dense layer of cancellous bone which separates the cavity from the posterior fossa.

(*b*) *Inner aspect of the squama or outer walls of the middle ear tract.*

FIG. 11.—AT BIRTH.

Left bone. Squamo-zygomatic portion and tympanic ring with the membrane and ossicles in position Outer aspect.

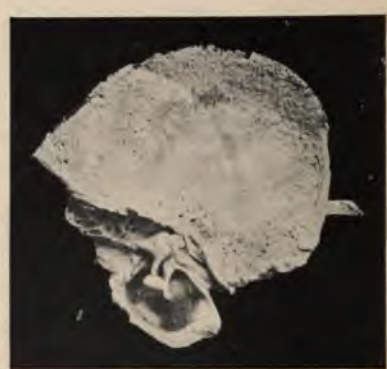

FIG. 12.—AT BIRTH

Left bone. Squamo-zygomatic portion and tympanic ring with the membrane and ossicles in position. Inner aspect.

On looking at the inner aspect of the squama it is seen that the back part of the posterior triangular process where it forms the outer wall of the antrum, is lined with fine cells which are always present at birth and can be distinguished all through life. In front of the cells the bone is smooth, where it forms the outer attic wall. Lying against

the outer attic wall are the head of the malleus and body and posterior process of the incus,—a point to be remembered in removing the ossicles.

As before stated, the outer wall of the middle ear is formed above by the outer attic wall, which extends slightly downwards and backwards overhanging the posterior superior part of the middle ear, and by the membrane with the embedded handle of the malleus.

(iii) *Anterior and posterior middle-ear walls.*—

FIG. 13.—INFANT.

Left bone. Section through the middle ear showing the anterior and posterior walls. The membrane and ossicles removed. The section passes through the vestibule.

If a lateral vertical section is made through the middle ear, the anterior and posterior walls can be examined.

The posterior middle-ear wall shows: above the triangular opening of the attic into the antrum; the base formed by the common roof; the inner wall by the external canal which has the Fallopian canal attached to it anteriorly and inferiorly; and

the outer by the descending triangular process of the squama. The inner and outer walls meet below, forming the apex of the opening in which is lodged the tip of the posterior process of the incus.

Below and internal to the apex of the opening is the pyramid for the stapedius tendon, attached to the inner surface of the Fallopian canal in its downward course after it has left the shelter of the external canal. On each side of the pyramid is a fossa.

The inner or sinus tympani runs internal to the canal for the stapedius and Fallopian canal in an upward and backward direction; it is often of great depth, and may have the thin sulcus jugularis for a floor, and it often runs up to the outer wall of the vestibule below and behind the oval window.

One or more little bony processes are often seen running from the pyramid to the promontory across the upper part of its opening, and these, together with the stapedius tendon running across to reach the stapes, prevent the thorough clearing out of pus or *débris* which may collect in it.

In some cases the cavity cannot be properly cleared out with instruments without injuring the facial nerve, and any attempt to enlarge the opening must have the same result.

In using a guide to find the antral opening from the middle ear through the meatus, the instrument may pass into a deep sinus, with disastrous results to the nerve and canal.

The outer fossa varies ; sometimes it is a simple recess, sometimes a pocket with the opening above, a condition which is produced by the upturning free border of the floor of the middle ear. Occasionally it runs for a considerable distance outside the facial nerve.

The anterior middle-ear wall shows the floor of the middle ear turning upwards towards the roof to form part of the opening of the Eustachian tube and tensor tympani canal, the latter being above and internal to the former with a ledge between them. The wall is usually cellular, and as it, together with the inner wall of the tubal opening, is formed by the thin carotid canal, the danger in dealing roughly with the cells is apparent. Infection of the carotid artery is, curiously enough, a very rare complication of middle-ear suppuration.

It is also seen that the floor is on a lower level than the mouth of the Eustachian tube.

(3) CONSISTENCE OF THE OUTER ANTRAL WALL AND MASTOID MASS AT BIRTH

FIG. 14.—INFANT.

Left bone. Section through the antrum and mastoid mass.

If a vertical lateral section be made behind the stylo-mastoid foramen through the antrum and mass of bone from which the mastoid process is formed, it will show the outer antral wall to consist of an outer layer of compact bone with an inner layer of fine cells, while the bone below, from which the process is formed, is as a rule, densely diploetic. There is usually a thin layer of compact bone separating the antrum from the diploetic mastoid mass below. Sometimes the mastoid mass is composed mainly of dense ivory bone and remains so all through life.

(4) THE PETROUS CELL

There is often seen quite a large cell lined with compact bone below and internal to the cancellous

mass, just behind the descending part of the facial nerve, which indeed, sometimes runs through the cell before emerging at the stylo-mastoid foramen. At the fifth and sixth months of fœtal life a mass of cartilage occupies the anterior inferior aspect of the bone below and anterior to that from which the mastoid process is formed. As this cartilage becomes ossified the bone closes over to form the stylo-mastoid foramen and leaves internally this densely lined cell from which foramina open, for the passage of vessels to the surrounding parts. Sometimes there is an extra opening into the cell below and behind the stylo-mastoid foramen for the stapedius muscle. This cell must not be confounded with the mastoid cells, and for want of a better name I call it the "petrous" cell. It

FIG. 15.—SEVEN MONTHS.

Right bone, showing smooth-lined "petrous" cell below and internal to the mastoid mass.

FIG. 16.—TWO YEARS.

Right bone, showing "petrous" cell the outline dotted in ink.

apparently forms in connection with the development of the descending part of the facial canal, the stapedius muscle and the chorda tympani, and, as far as I know, it is not of surgical importance.

B. THE SURGICAL ANATOMY OF THE LABYRINTH

The petrous portion of the bone contains the labyrinth, and as the parts of the labyrinth do not alter in relation to one another, and the guides are the same all through life, the surgical anatomy of the labyrinth can now be considered.

(1) THE SURGICAL IMPORTANCE OF THE LABYRINTH

We have seen that the internal wall of the middle ear and antrum is formed by the outer part of the bony labyrinth which lies entirely in the petrous portion of the bone.

Implication of the labyrinth is therefore fairly frequent as a result of middle-ear suppuration, the most frequent points of invasion being the external semicircular canal and the neighbourhood of the round and oval windows. (Milligan, Whitehead, Victor Hinsberg, Jansen, &c., "Transactions of the Otological Society," vol. v. pages 25 and 49.)

When once the interior of the labyrinth is infected disease may spread to the interior of

the cranium, more especially to the posterior fossa through the internal auditory meatus and the aqueductus vestibuli.

As the bony labyrinth, except where it comes to the surface, is enclosed during infancy in cancellous bone, total or partial exfoliation sometimes takes place as a result of extension of disease from the middle-ear tract, and this tendency to exfoliation is most frequently seen in cases of tuberculous disease which spreads along the cancellous covering. Internal and posterior to the cochlea is a large mass of cancellous bone which may communicate with cells from the middle ear in front or below, or with mastoid cells passing below the labyrinth.

The semicircular canals are more prone to exfoliation, as they are separated from one another in infancy by cancellous bone; later in life they become more or less joined together by bone of ivory hardness.

Charles Ballance, in the "Transactions of the Otological Society," vol. i. p. 48, relates the case of a woman who suffered from discharge from the left ear, vertigo, tinnitus, and deafness. During the radical operation pus was found oozing from the semicircular canal region (the inner wall of the antrum), and in dealing with it the canals were in part destroyed and the back of the vestibule opened. As a result the vertigo and tinnitus ceased and the hearing was markedly improved, but some deterioration in that respect took place later.

Operations on the labyrinth have not been limited to cases in which suppuration has invaded its interior; for Richard Lake was the first to report a case of incapacitating vertigo with tinnitus and deafness, unassociated with suppuration, in which he removed the semicircular canals, with cure of the vertigo, improvement of the hearing, but with persistence of the tinnitus. The full report of this pioneer case will be found in the "Transactions of the Otological Society," vol. v. p. 69.

He has also dealt with the cochlea and vestibule in a case of distracting tinnitus with encouraging results. ("Transactions of the Otological Society," vol. vi. p. 60.)

Operations of the same nature have also been performed by Milligan. (*Journal of Laryngology*, February 1905, p. 105.)

A new field has thus been opened for the relief of these most distressing cases of tinnitus and vertigo. It has been proved that the removal of the canals and attacking the vestibule does not result in deafness, for in the case referred to of Ballance's and in the first case of Lake's the hearing was improved while the vertigo disappeared. Therefore if an operation is demanded for auditory vertigo it is sufficient to deal with the canals and vestibule, and it may in the future be found that the ampullary nerves can be destroyed immediately after passing through the inner wall of the vestibule, rendering it unnecessary

to remove the ampullary ends of the semicircular canals.

If tinnitus is the reason, the cochlea and perhaps the vestibule must be dealt with in order to destroy the nerve endings. Division of the auditory nerve is an alternative operation for tinnitus; but this, together with the cochlea operation, must result in complete loss of function; there are very few patients who desire to rid themselves of tinnitus at the expense of any hearing they may have, but there are some certainly.

If incapacitating vertigo and tinnitus demand operation it is still a question which is the better procedure,—destruction of the bony labyrinth and the nerve endings or division of the auditory nerve.

These operations have hitherto been performed for the cure of the symptoms of vertigo or tinnitus or both, as a last resource.

The combined symptoms of vertigo and tinnitus occur in what is known as Ménière's disease which results in more or less loss of function. The pathology of this disease is not clear for it is never fatal, but we know that hæmorrhage into the labyrinth may cause the symptoms, for such a condition was found in Ménière's classical case.

It cannot, however, be supposed that hæmorrhage occurs in all patients who suffer from these symptoms; increased tension, due to increase in the perilymph or endolymph or to block in their circulation, is a possible explanation. Ménière's

disease is clinically somewhat analogous to glaucoma. The course may be fulminating, acute, subacute, or chronic. The tinnitus corresponds to the flashes of light, and both lead to loss of function.

If increased tension is the correct explanation, it is possible that some operation on the canals or vestibule can be undertaken, not only for the cure of the vertigo and tinnitus, but for the preservation of hearing.

In the "Archives of Otology," vol. xxvi., I proposed that the external canal should be opened for Ménière's disease and in the light of Lake's work some such operation becomes more feasible.

Before dealing surgically with the labyrinth a wide opening into the antrum and middle ear must first be made to expose the guides, viz., the anterior crus of the external canal and the inner middle-ear wall. The method of doing this and the attendant dangers will be subsequently described.

In all operations on the labyrinth, meningitis caused by extension along the aqueducts and nerve-sheaths is one of the greatest dangers, and can only be avoided by strict antiseptic precautions.

A fine burr will be found to be the safest implement to work with.

(2) THE LABYRINTH AS A WHOLE

If we take a fœtal or an early infantile petrous and remove the cancellous covering, the bony laby-

FIG. 17.—AT BIRTH.

Left bone. The squamo-zygomatic and tympanic ring separated from the petrous in which lies the bony labyrinth.

rinth is exposed, and the parts of that structure which appear on the inner wall of the middle-ear tract can be readily recognised.

FIG. 18.—AT BIRTH.

Left bony labyrinth dissected out, showing the course of the facial nerve marked on in ink.

The bony labyrinth consists of three main divisions: (1) the semicircular canals, externally;

(2) the vestibule in the middle; and (3) the cochlea, internally; all three are in direct communication.

Inside the bony is the membranous labyrinth, a closed sac containing endolymph, which forms a connection, as we have seen, with the saccus endolymphaticus through the aqueductus vestibuli. The interval between the bony and the membranous labyrinth contains perilymph, which communicates with the subarachnoid space through the aqueductus cochleæ.

(3) THE FACIAL NERVE IN RELATION TO THE LABYRINTH

The facial nerve is wrapped round the bony labyrinth, and, as it lies in infancy, so it remains all through life, the only changes being that its descending portion becomes deeper and longer during subsequent growth.

After entering the foramen at the anterior superior corner of the outer extremity of the internal auditory meatus it runs forwards and outwards with a gentle curve, soon becoming exposed at the hiatus where it lies between the top of the cochlea and the anterior extremity of the superior canal round which it winds. It then passes closely in front of the anterior extremity of the external canal, becoming attached to its anterior inferior aspect, and bending backwards runs over the oval window and sinus tympani. It then leaves the shelter of the canal to descend with a gentle

inclination outwards. In this descending course the inferior crus of the posterior canal leans towards it. It is sometimes thought that facial paralysis during infection of the middle-ear tract means that the labyrinth is involved, but we see that the nerve is entirely outside the labyrinth and can therefore be involved apart from it.

(4) THE SEPARATE PARTS OF THE LABYRINTH

(1) The semicircular canals are three in number, each having an ampullated or enlarged extremity containing the auditory nerve endings. These ampullated ends are the special objects in operations such as that of Lake's.

(*a*) *The external canal* runs horizontally. The anterior extremity is ampullated and opens into the junction of the outer wall and roof of the vestibule just above the oval window and external to the anterior extremity of the superior canal. It then curves backwards and coming to the surface in front forms the inner boundary of the antral opening into the attic; it then becomes buried in the inner antral wall and opens again into the vestibule at the lower and back part of its outer wall. This canal is a guide in performing the radical operation, in opening the vestibule and in dealing with the other canals. The dangers in dealing with it are: (1) injuring the facial nerve; and (2) injuring the dura mater of the middle fossa at the anterior extremity.

(*b*) *The posterior canal* runs vertically and at a right angle to and behind the external. It opens above into the posterior wall of the vestibule by a crus common to it and the posterior crus of the superior. In its course outwards it is at first parallel to the posterior surface of the petrous, where its outline is visible in early life; it then curves outwards and downwards becoming more buried, and after embracing the posterior limb of the external canal it runs upwards and inwards to open into the floor of the vestibule with an ampullated extremity.

It reaches as low as the opening of the round window, with its inferior limb lying on the back part of the sulcus jugularis. In its inferior course it closely approaches the descending part of the facial nerve.

The dangers in dealing with it are: (1) injuring the dura mater of the posterior fossa; (2) injuring the sulcus jugularis, though in the adult the wall between may be thick; and (3) injuring the facial nerve in its descending course.

(*c*) *The superior canal* runs upwards and forwards from the junction with the posterior, and forms the highest point on the superior surface of the petrous portion, becoming buried at its anterior ampullated end, round which the facial nerve winds, before opening into the roof of the vestibule alongside of and immediately internal to the anterior opening of the external canal. It will be noticed that the superior canal is placed

altogether on a higher level than the rest of the labyrinth.

The dangers in dealing with it are: (1) injuring the dura mater in both the middle and posterior fossæ, the former especially if the middle fossa dips down externally to it; (2) injuring the superior petrosal sinus which runs across its curve; (3) injuring the facial nerve as it winds round its anterior extremity.

(2) *The vestibule* is in the intermediate cavity between the semicircular canals and the cochlea. It is capable of holding about one minim of water, and is roughly wedge-shaped with the edge forwards.

FIG. 19.—TWO YEARS.

Left bone. Lateral vertical section through the internal auditory meatus and the vestibule immediately behind the oval window. The parts outlined in ink.

The roof is on a level externally with the top of the oval window with the facial nerve running over it, and internally with the roof of the internal auditory meatus. It receives the opening of the

anterior crus of the superior semicircular canal immediately internal to the opening of the anterior crus of the external canal.

The posterior wall is occupied by the common opening of the posterior and superior canals.

The floor has the lower opening of the posterior canal behind, and in front it opens into the cochlea just below the oval window. It is on the level of the lower part of the posterior edge of the oval window externally and of the floor of the internal auditory meatus internally.

The inner wall meets the outer wall in front on the vertical plane of the anterior boundary of the oval window. It forms the partition between the cavity and the bottom of the internal auditory meatus, which is thin and perforated for the passage of nerves.

The outer wall has the posterior opening of the external canal behind and the oval window in front, with an intervening piece of bone which at its lower part, below and behind the oval window, separates the vestibule from the sinus tympani.

FIG. 20.—CHILD.

Left bone. Lateral vertical section through the vestibule and internal auditory meatus behind the oval window.

The oval window and stapes point at an angle to the inner wall of the vestibule, and, therefore, to the internal auditory meatus. The anterior edge of the oval window corresponds to the anterior wall of the internal auditory meatus.

The two guides to the vestibule are the oval window in front and the external semicircular canal behind, the facial nerve running between them.

If attempts, beyond removing the stapes, are made to open the vestibule in front, the facial nerve will be in danger above and the cochlea below. In some cases of suppuration it is necessary to disregard both; in fact, it may be necessary to deal with the cochlea at the same time; and injury to the facial nerve has lost a great deal

of its terrors since joining the facial to the hypoglossal has been introduced, an operation with which the names of Charles Ballance and Purves Stewart must always be associated.

The other and better way of opening the vestibule is through the external canal area. After removing the posterior half of the canal an opening can be made inwards and forwards through the outer wall.

It may be necessary to use both routes, in which case the bridge between the two containing the facial nerve can be left intact if the case warrants it.

(3) *The cochlea* is partly situated in the front part of the inner wall of the middle ear and partly in the inner wall of the carotid canal, slanting forwards and inwards. It begins just below the oval window, the outer wall of the beginning of its first turn being represented by the promontory.

FIG. 21.—CHILD.

Left bone. The anterior meatal wall and the outer wall of the carotid canal removed, showing the relation of the cochlea to the inner wall of the carotid canal.

After reaching the floor of the middle ear the bony tube, for such it is, coils upwards and outwards upon itself two and a half times, the coils becoming smaller and smaller and forming the well-known snail-like structure. The end of its first coil reaches nearly to the anterior boundary of the oval window, and has the facial nerve lying between it and the anterior extremities of the superior and external semicircular canals.

The base is, as we have seen, formed by the anterior part of the outer extremity of the internal auditory meatus, its outer edge being in the vertical plane of the anterior edge of the oval window.

FIG. 22.—THREE YEARS.

Left bone. The roof of the middle-ear tract, cochlea, vestibule, and internal auditory meatus removed. The stapes in position.

The direction of the apex of the cochlea from the base is forwards, outwards and upwards, and points into the canal for the tensor tympani or just below it, on a level with the mouth of the Eustachian tube.

FIG. 23.—CHILD.

Right bone. A vertical section on a level with the anterior border of the malleus, exposing the middle ear and the cochlea. The malleus and the posterior segment of the membrane remain *in situ*.

The upper limit of the cochlea corresponds closely with the upper edge of the Fallopian canal above the oval window.

The anterior limit is internal to the mouth of the Eustachian tube. There is about as much internal to the mouth of the tube as there is from the anterior edge of the oval window to the mouth. The internal carotid artery lies against its anterior-inferior aspect, but may, in the adult, be separated by cells extending inwards from the middle-ear floor.

The inferior limit is the floor of the middle ear which may project upwards in the adult for a considerable distance.

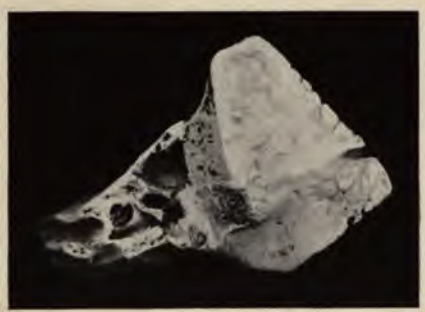

FIG. 24.—INFANT.

Left bone. The inner middle-ear wall exposed and the outer wall of the cochlea opened. A rim of the promontory remains below the oval window.

The dangers in opening it are: (1) injuring the facial nerve as it lies between the upper part of the cochlea and the anterior extremities of the external and superior semicircular canals, and as it lies above the oval window; (2) injuring the jugular bulb which often lies against its first turn inferiorly; (3) injuring the internal carotid artery which lies against the lower and inner part of the outer wall; and (4) injuring the dura mater of the middle fossa.

FIG. 25.—INFANT.

Left bone. A wide radical operation has been performed, and the semicircular canals have been dissected out.

To sum up: a wide radical operation having been performed, the anterior crus of the external canal is exposed where it forms the inner boundary of the opening of the antrum into the middle ear; if this canal is traced backwards it will lead to the posterior canal before curving inwards to open into the back part of the outer wall of the vestibule; while if the anterior limb to which is attached the facial nerve, be followed forwards it will lead to the anterior limb of the superior canal and the roof of the vestibule; the posterior canal will lead to the posterior extremity of the superior canal above, and to the floor of the vestibule below.

The cochlea can be opened below and internal to the oval window, the burr working forwards and inwards, great care being taken that it does not slip—upwards to the facial nerve, forwards to the internal carotid artery, or downwards to the jugular bulb. The opening should be limited to the inner middle-ear wall where the outer cochlea wall can be under observation.

LECTURE II

A. SUPERFICIAL CHANGES IN THE BONE DURING GROWTH

THE bone as a whole gradually becomes lateralised and upright. The growth takes place external to the outer walls of the middle ear and antrum which remain practically the same as at birth.

(1) OUTER ASPECT

(i) *Formation of the bony meatus.*—The roof and the posterior-superior walls are formed by the squama, while the anterior, inferior and posterior-inferior walls are formed by the tympanic ring.

Two tubercles appear on the tympanic ring, one near the top of the anterior limb and another at a corresponding point at the junction of the inferior and anterior parts. These gradually grow outwards and approach one another eventually meeting at their outer extremities, forming with the outspreading anterior margin of the ring a foramen which gradually becomes filled in. After the junction the plate of bone so formed grows outwards, becoming thick and irregular at its outer extremity, thus

forming the anterior meatal wall. At the same time the inferior margin grows outwards to form the inferior wall, becoming slightly convex towards

FIG. 26.

SIX MONTHS. TWENTY-TWO MONTHS.
SIX YEARS. TWENTY YEARS.

Left bones, showing the formation of the bony meatus.

the meatus and thick and irregular at its outer extremity.

The posterior limb gradually spreads outwards over the outgrowing squama to form the posterior-inferior part of the posterior wall.

FIG. 27.—TWENTY YEARS.
Left bone. Showing fully formed bony meatus, spine and mastoid process.

Exostoses and hyperostoses of the meatus are always caused by thickening of some part of the tympanic plate.

The squama immediately above the attic grows outwards and bends over to form the roof, becoming slightly concave to the meatus, while the posterior wall is completed by the growth outwards of the squama behind the outer attic wall where it overhangs the posterior-superior aspect of the middle ear.

As the posterior-superior wall grows outwards and the outer antral wall increases in thickness, the cells lining the outer antral wall come into relationship at their anterior aspect with the meatus at its deep posterior-superior part, thus forming a narrow, sometimes thin, sometimes dense, anterior wall to the antrum. It is here that the typical

sagging, caused by œdema, in cases of acute retention of pus in the antrum occurs and where perforation in infancy sometimes takes place.

(ii) *The outer antral wall.*—After forming the posterior-superior meatal wall the triangular process of the squama bends backwards to form the triangular outer wall of the antrum which gradually increases in thickness. The outer antral wall is usually pierced by numerous small foramina for the passage of vessels. It varies in extent and is, as a rule, situated immediately behind the posterior-superior meatal border which marks its anterior limit; while the extension backwards of the posterior-zygomatic line, after it has formed the upper limit of the meatus, marks its base; and an imaginary line drawn upward from the level of the posterior meatal wall to the posterior-zygomatic line marks the posterior line. This triangle is known as Macewen's.

The posterior-zygomatic line varies greatly and is occasionally absent in the adult, especially in females and poorly marked bones.

(iii) *The spine.*—At the place where the triangular process bends backwards the spine gradually appears. At first it is represented by a triangular ledge with the apex downward and slightly forward, becoming later a distinct tubercle, and when fully formed it appears as a raised triangular ledge of bone on the edge of the posterior-superior meatal wall pointing outwards and forwards into the meatus and being attached to the posterior-zygomatic line above. There is

often a marked depression or short canal immediately above and behind it. The spine points inwards to the lower part of the opening of the antrum into the attic or just below it; at any rate the opening is never below its level. It will be seen that it is situated at the apex of Macewen's triangle and that it marks in a horizontal line the lowermost part of the antrum unless that cavity is large or highly placed. Sometimes it is entirely absent.

(iv) *The formation of the mastoid process.*—The process is formed below the antrum by the descending part of the triangular process anteriorly, and by the petrous posteriorly and inferiorly, the former overlapping the latter. The masto-squamosal suture closes early in infancy but evidences may be seen all through life.

The process begins to develop as soon as the child begins to use the big neck muscles. That the process is formed simply for the attachment of the muscles and has no auditory function is strongly suggested by a case reported by Purves Stewart in "Brain," 1904, page 89. A man had congenital absence of the large neck muscles on one side with complete absence of the mastoid process.

The process gradually increases in size; it eventually consists of an upper part corresponding with the main mass of the bone and reaching from the antrum as low as the inferior level of the inferior bony meatal wall, and a lower part which projects into the neck over the digastric fossa; with the formation of this lower mastoid the squama takes a small part.

(2) INNER ASPECT

(i) *The superior surface.*—The portion of this surface external to the line of the superior semicircular canal is nearly horizontal, while the part containing the labyrinth has a twist and points upwards, forwards and outwards. The outer horizontal part

FIG. 28.—TWENTY YEARS.
Left bone. Showing the superior surface.

is subject to a varying degree of moulding by the growth of the temporo-sphenoidal lobe.

The petro-squamosal suture closes during the first six months of life, but a process of dura mater is lodged under the edge of the tegmen, and there are sometimes marked connections with the middle ear and the petro-squamosal sinus by means of emerging veins. The sinus may persist all through life

producing grooving and canalisation along the line of the suture.

The projection of the arch of the superior semicircular canal varies in its relation to the general height of the surface; often it projects boldly; sometimes it is nearly flush with the surface; while at other times the part external to it is quite as high, but there is a marked dip internally. This is of importance, as the canal is used as a guide in dividing the auditory nerve by Parry's route.

The hiatus Fallopii becomes more shut in by the growth of bone over it from externally.

(ii) *The posterior surface.*—This surface external to the posterior semicircular canal is also subject to a varying amount of moulding by the growth of the cerebellum and lateral sinus.

The groove for the lateral sinus becomes more upright and more marked, that on the right side being, as a rule, deeper, broader and more forward than the left. The mouth of the aqueductus vestibuli becomes a slit with a smooth surface below and internal to it for the saccus endolymphaticus.

The outline of the superior arch of the posterior canal and its junction with the superior canal becomes less marked or lost. The fossa under the superior canal becomes almost obliterated by the growth of bone inwards over it, and is represented by a slit of varying size situated externally to the internal auditory meatus.

The internal auditory meatus becomes deeper by the inward growth of bone. The measurement of

the inner lip from the level of the most projecting part of the superior canal averages half an inch in the adult. Below the meatus is seen the upper border of the jugular foramen, with a triangular process of bone projecting downwards and corresponding to the inner boundary of the sulcus

FIG. 29.—TWENTY YEARS.
Left bone. Showing the posterior surface.

jugularis, and separating it from the aqueductus cochleæ which becomes situated on the border just below the internal auditory meatus.

(iii) *The border between.*—The outer part which in infancy is rounded and composed of cancellous bone is thinned and moulded between the cerebrum and cerebellum and lateral sinus in a varying degree; it may be grooved for the superior petrosal

sinus for its whole distance, often, however, the groove only extends inwards as far as the superior canal.

The sinus lies sometimes on the superior surface of the border; sometimes it lies below the border right on the posterior surface, especially in the outer part of its course.

It often lies on the superior surface internal to the canal. The variation of the grooving produced by the sinus is of importance in dividing the auditory nerve by Parry's route.

(3) THE INFERIOR ASPECT

The chief changes seen here are: the formation of the digastric fossa, the projection downwards of the mastoid process, the ossification of the styloid process and the deepening of the sulcus jugularis and carotid canals by the growth downwards of their surrounding partitions. The depth of the sulcus varies extremely and is of surgical importance. It will also be observed that the stylo-mastoid foramen appears on this surface in the angle between the mastoid and styloid processes and the junction with the occipital.

B. THE RELATION OF THE LATERAL SINUS TO THE SURFACE

In infancy the sinus lies in a horizontal position below and behind the antrum and separated from it by dense cancellous bone rendering infection unlikely, but as growth takes place it adopts a more upright course coming into closer relationship with the posterior wall of the antrum and the upper part of the mastoid process.

FIG. 30.—SIX MONTHS.

Right bone. The anterior edge of the lateral sinus marked in ink.

As a broad rule the sinus on the right side is larger and placed farther forward than on the left, but no reliance can be placed on this, for it is sometimes far back on the right side and well forward on the left.

FIG. 31.—ADULT.

Right bone. Showing the lateral sinus lying far back.

At the upper part of the bone it may, in extreme cases, run right up to the posterior wall of the antrum, and may even dip into the outer wall of the cavity almost completely shutting it out from the surface.

FIG. 32.—ADULT.

Right bone. Showing the lateral sinus well forward.

It may encroach on the apex of the antrum or run right up to the posterior meatal wall immediately below it, taking the place of the upper mastoid cells, or perhaps leaving a thin tract of cells or diploe anteriorly leading to a larger collection of cells or diploe in the projecting part of the process.

FIG. 33.—FIFTY-SIX YEARS.
Left bone. Showing the lateral sinus well forward.

FIG. 34.—FIFTY-SIX YEARS.
Left bone. Inner aspect of previous specimen.

It may be separated from the surface immediately behind the antrum by thin translucent bone, so it would be wounded immediately if a wide or careless opening was being made.

FIG. 35.—ADULT.

Right bone. Showing the lateral sinus encroaching on the posterior part of the antrum. A very thin translucent plate of bone (dotted round) separates the sinus from the surface immediately behind the antrum.

The very forward sinus may be seen quite early in life; I have a very marked one in the right bone of a child aged three years.

FIG. 36.—THREE YEARS.
Right bone. Showing forward lateral sinus.

A forward sinus is in the way during the radical operation, in exploring the cerebellum, during operations on the labyrinth and when the facial nerve is divided by the route adopted by Cuthbert Wallace.

It has been claimed that a forward sinus may be diagnosed if a suitably bent probe passed into the antrum from the meatus is soon arrested by the posterior wall of that cavity. Such a conclusion cannot be accepted, for a small antrum frequently exists with the sinus far back and a large antrum may be present with a forward sinus.

Membranous septum inside the lateral sinus.

I once found a membranous septum inside the left lateral sinus of a man aged forty years, stretching across the interior and dividing the channel

into two passages for half an inch in the vertical part. Such a condition is very rare. It would be awkward if it was present in a case of septic thrombosis.

FIG. 37.—FORTY YEARS.

Left bone. Showing a membranous septum in the interior of the lateral sinus.

C. CONSISTENCE OF THE OUTER ANTRAL WALL AND MASTOID PROCESS

(1) ABSENCE OF CELLS

At birth and up to about the age of five years, a lateral vertical section through the outer antral wall and mastoid mass shows, as we have seen, that the former is composed of an external layer of thin compact bone lined internally by a layer of fine cells having an inward direction, and where the antrum abuts on and the squama overlaps the diploetic mastoid mass there is a separating layer of compact bone of varying thickness.

Under these conditions suppuration in the antrum may perforate the outer wall forming an abscess high up behind the auricle with occasionally great extension over the side of the head; or it may perforate the anterior wall into the meatus at its deep posterior-superior aspect. This infantile condition often remains all through life and forms a common type.

FIG. 38.—SIX YEARS.

Right bone. Showing the outer antral wall and the overlapping squamous portion of the mastoid to be dense, with marked line of demarcation between the dense squamous and diploetic petrous portion of the mastoid process.

FIG. 39.—ELEVEN YEARS.
Right bone. Showing dense outer antral wall and a diploetic mastoid process.

The outer antral wall and the separating layer between the antrum and mastoid mass increase more or less in thickness and are of great density.

The cells which line the outer antral wall remain distinct and the mastoid process remains diploetic.

Occasionally the overlapping dense squama may be seen sharply marked off from the petrous part of the mastoid process, as in Fig. 38.

It seems then that the formation of cells depends on the density of the separating layer.

The thickest outer antral wall I have seen was under these circumstances, in a man aged nineteen years; it measured three-quarters of an inch.

FIG. 40.—NINETEEN YEARS.

Right bone. Showing dense antral walls and a diploetic mastoid process. "Infantile" form of mastoid process. The outer antral wall is three-quarters of an inch in thickness.

Very rarely the mastoid process instead of being diploetic is of ivory density; this again is apparently originated in early life, for the mastoid mass in infancy instead of being diploetic is sometimes nearly entirely of ivory density.

FIG. 41.—ADULT.

Left bone. Showing dense outer antral wall and a mastoid process of almost ivory density.

With such conditions suppuration in the antrum is of special danger; being unable to extend outwards or downwards it more readily extends to the middle or especially the posterior fossa, and that without any external gross signs such as œdema and redness, and even tenderness may be difficult to elicit.

The difficulty in operating is obvious and is infinitely increased when a forward sinus or a highly placed antrum, or both, are also present.

FIG. 42.—THIRTY-THREE YEARS.

Right bone. Showing dense outer antral wall and diploetic mastoid, with a highly placed antrum. The lower ink-mark indicates the position of the spine and the ledge above it is the posterior-zygomatic line.

(2) THE PRESENCE OF CELLS

(i) *Formation and spread.* — The mastoid cells extend from the apex of the antrum, sometimes at all events, in connection with the line of junction of the squamous and petrous portions, into the squamous and petrous portions composing

FIG. 43.—FIVE YEARS.

Left bone. Showing early formation of mastoid cells.

the mastoid process. They may remain limited to the upper part of the process, or they may extend upwards through the squamous portions into the outer antral wall, or downwards through the petrous portion into the lower part of the mastoid, or both upwards and downwards, and in each direction they may have further extensions.

However limited or extensive they may be they are always in connection with one another, and directly or indirectly with the cavity of the antrum.

Upon them depends largely the direction in which infection spreads when once the antrum is affected. It is important, therefore, for the surgeon to know in what direction spread may be expected and what conditions may be met with during operation.

(ii) *The chief types in the adult are :*

(*a*) The cells limited to the upper mastoid region with a dense outer antral wall and a diploetic or rarely a dense lower mastoid.

FIG. 44.—ADULT.

Right bone. Showing cells in the upper part of the mastoid process with a dense outer antral wall and a diploetic condition of the lower part of the mastoid. A distinct but thin layer of compact bone separates the mastoid cells from the diploe.

(*b*) The cells extending downwards and occupying the upper and lower mastoid entirely or with a rim of diploe at the extreme tip, the outer antral wall remaining dense.

FIG. 45.—ADULT.

Left bone. Showing the cells extending nearly to the tip of the mastoid process, which is diploetic. The outer antral wall is dense.

Some variations of this condition are :

(*a*) A narrow track of cells running through the upper mastoid, leading to a large cell or series of large cells in the lower mastoid which may have large extensions backwards.

FIG. 46.—ADULT.

Right bone. Showing a track of cells leading to a large cell in the tip of the process. This cell has a large extension backwards. The outer antral wall is dense.

(β) A track of cells with extremely dense walls running through the upper and lower mastoid.

FIG. 47.—ADULT.

Right bone. Showing a narrow tortuous track of cells with very dense walls running through the entire mastoid. The outer antral wall is dense and the antrum highly placed.

(*c*) The cells extending chiefly upwards into the outer antral wall between the outer compact layer and the fine cells and leaving the lower mastoid diploetic or dense.

FIG. 48.—ADULT.

Right bone. Showing cells in the upper mastoid and outer antral wall. The lower mastoid is diploetic.

FIG. 49.—ADULT.

Left bone. Showing cells in the upper mastoid and in the outer antral wall. The lower mastoid is dense.

(*d*) The cells extending both upwards and downwards with or without a rim of diploe at the tip of the mastoid.

FIG. 50.—ADULT.

Right bone. Mastoid cells extending both upwards and downwards. The cells in the outer antral wall are marked off from the inner fine cells by a distinct line of demarcation.

The cells may be limited to these positions but extension occurs in each situation and I propose

to describe the cells, their relations and extensions from above downwards, viz.:

Those in the outer antral wall.

Those in the upper mastoid.

Those in the lower mastoid.

(iii) *The cells and their extensions.*

(*a*) *The cells in the outer antral wall and their extensions.*—As these cells spread from below upwards they are always associated with cells in the upper mastoid. An examination of the outer antral wall in 210 specimens of all ages above the age of five years showed that the outer antral wall was

Dense in 97

Cellular in 113 { Coarsely cellular in 64 / Densely cellular in 49

and the fact that the cells in the wall, apart, of course, from the fœtal cells, were always associated with cells in the upper mastoid was very clear. The ascending cells are coarser than the antral cells which are fine and have an inward direction, and there is often a distinct layer of compact bone between the two sets (*see* Fig. 50).

FIG. 51.—ADULT.

Right bone; from above. The roof of the antrum has been removed. The outer wall of the antrum is cellular, and the upspreading cells are seen to be coarse and to have a vertical direction, thus marking them off from the inner fine cells, which have an inward direction. The posterior antral wall is also coarsely cellular. Cells also extend inwards over the semicircular canal.

The cells may be small or large. Sometimes a single large one is present and may easily be mistaken for the antrum, but it is usually just below the outer compact layer and a probe will not pass into the attic.

FIG. 52.—ADULT.

Right bone. Showing a large cell in the outer antral wall which might be mistaken for the antrum, which lies deeper.

A rare condition is for a large cell in the outer antral wall to communicate with coarse cells which run down to the digastric fossa internal to the mastoid process, and having a very thin wall through which suppuration may perforate into the neck, leading to a collection of pus under the deep fascia, with perhaps extensive burrowing, and without affecting the mastoid process at all.

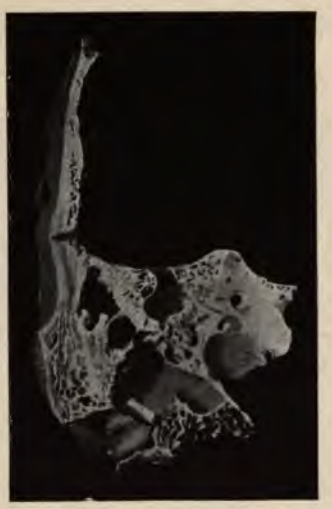

FIG. 53.—ADULT.

Right bone. Large coarse cells in the outer antral wall running down to the digastric fossa, where there is a very thin bony partition. The mastoid is diploetic. The cells are invading the occipital.

Extension of these cells may take place: *Upwards*, invading the diploe of the squama.

FIG. 54.—CHILD.

Right bone. Showing the cells extending well up into the squama.

Forwards, over the roof of the meatus and even into the base of the zygoma.

FIG. 55.—ADULT—TWENTY-FIVE YEARS.

Right bone. Showing the cells extending into the roof of the meatus.

FIG. 56.—ADULT.

Showing the cells extending over the roof of the meatus into the base of the zygoma.

Suppuration may extend from the antrum into these upward and forward extensions, forming a

fairly large cavity which may be mistaken for a high antrum; if rough attempts are made to enlarge the supposed antrum into the attic, or if the examining probe is used roughly the dura mater of the middle fossa may be perforated. The facts that the cavity is superficial and far forwards and that a probe, gently used, will not pass easily into the attic, will arouse suspicion.

Backwards, reaching behind the antrum. A specially large cell is occasionally seen behind and communicating with the antrum. This cell has been specially described by Elsworth, of Cardiff, who proposed for it the name of "accessory antrum."

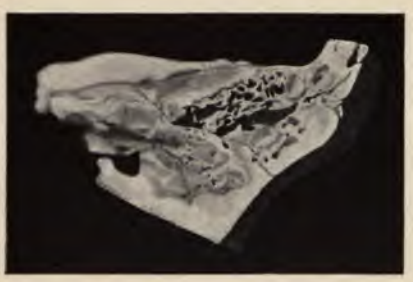

FIG. 57.—ADULT.

Left bone. Showing cells behind and above the antrum with the specially large cells, the "accessory antrum" of Elsworth.

(*b*) *The cells in the upper mastoid and their extensions*.—These are of varying vertical extent depending on the size of the antrum from the apex of which they extend to the lower level of the inferior bony meatal wall.

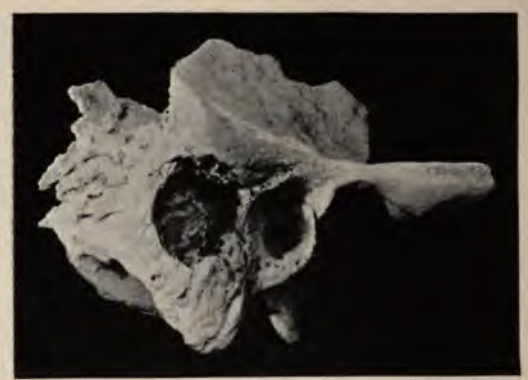

FIG. 58.—ADULT.

Right bone. The outer wall of the upper mastoid cells has been removed together with the cells themselves. The thin curved bony probe of the lateral sinus is exposed behind.

Their relations are :

Anteriorly, with the meatus where perforation sometimes occurs, forming a swelling discharging pus just inside the meatus on the posterior wall and closely resembling a furuncle.

Posteriorly, with the lateral sinus from which they are separated by a thin, translucent, curved bony partition. The sinus may come very far forwards converting these cells into a mere track which may lead to a cell or mass of cells in the projecting part. Here the cells often extend backwards over the lateral sinus.

Externally, with the surface where perforation is often seen forming a high mastoid abscess.

Internally, they abut on the petrous below the labyrinth and are in relation to, but often separated from, the descending part of the facial

nerve and the jugular bulb by dense bone. There may not be a dense partition and the cells may run right up to these structures.

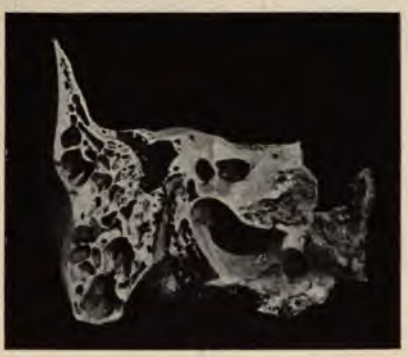

FIG. 59.—ADULT.

Right bone. The entire process and the outer antral wall are cellular. The cells extend inwards to the descending part of the facial nerve and to a high sulcus jugularis. The bone also demonstrates the pathway in Bezold's perforation.

The nerve may be here exposed or destroyed by disease and a high outpushing sulcus may become infected giving rise to pyæmia. If the sulcus is not high the cells may extend even further inwards, over the sulcus and under the labyrinth, and may effect a junction with the mass of diploe internal to the cochlea, perhaps running under the back part of the middle-ear floor on their way; they may also extend up to or even into the diploe of the occipital under the sulcus with a thin partition of compact bone between or an actual junction.

FIG. 60.—ADULT.

Left bone. The entire process and the outer antral wall are cellular. The cells extend inwards between the bony labyrinth and the sulcus jugularis up to the internal diploe. They also extend inwards to the diploe of the occipital bone below the sulcus jugularis.

Precautions in dealing with the Upper Mastoid Cells

In operating on cases in which these cells are involved, especially in acute cases, it is important to remove the outer wall carefully first, and not to touch the deeper parts until the cavity has been gently cleaned and thoroughly examined both with the finger and light; for it is not uncommon for the facial nerve to be naked in the anterior aspect of the bottom of the bony wound and for the lateral sinus, with its varying position, to be exposed. It is also possible for the jugular bulb to be exposed at the bottom of the wound behind the facial nerve. These exposures often take place quite early in acute infection.

(*c*) *The cells in the lower mastoid and their extensions.*

—The cells of the projecting part of the mastoid may not extend to the tip, which is then occupied by diploetic or dense bone; or they may occupy the whole process.

It is in this position that the mastoid cells attain their largest dimensions.

Perforation may occur:

Externally, forming a low mastoid abscess; at the tip among the attached muscles, or

Internally, forming what is known as a "Bezold's perforation," when the pus, being under the deep fascia, may burrow freely down the neck as in a digastric perforation (*see* Fig. 59).

FIG. 61.—ADULT.

Right bone. Showing large cells in the lower mastoid extending over the digastric fossa. The upper mastoid cells extend inwards under the labyrinth and up to the occipital diploe, where there is a thin bony partition. The antrum is highly placed; the upper ink-mark indicates the level of the posterior-zygomatic line and the lower mark that of the spine.

These cells may extend over the digastric fossa, forming a second route by which suppuration may

perforate it, or the cells may run upwards, backwards and inwards for a considerable distance external to and below the lateral sinus, and may communicate above with extension of cells from the outer antral and upper mastoid cells, forming a huge congeries of cells which may be perforated by disease at any part.

FIG. 62.—ADULT.

Right bone. Showing cells extending in every direction. The lateral sinus groove has been cleared of cells.

In dealing with suppuration in the lower mastoid it is sometimes necessary to remove it entirely.

(iv) *Age at which they appear.*—Although I have stated that the infantile condition of a compact outer antral wall lined with the fœtal layer of cells and a diploetic mastoid is present up to about the age of five years, yet the cells may be well

formed as early as two years; they are often present at seven or eight and are usually well marked at nine and ten or a little later.

FIG. 63.—TWO YEARS.

Right bone. Showing well-marked cells in the outer antral wall and entire mastoid.

FIG. 64.—NINE YEARS.

Left bone. Showing cells in the outer antral wall and entire mastoid.

D. VARIATIONS IN THE ANTRUM

(1) The antrum is very variable in size; it is often large in early childhood before consolidation

FIG. 65.—TWENTY-EIGHT YEARS.

Right bone. Posterior antral wall exposed, showing it to be composed of thin, translucent bone against which rests the cerebellum internally and the lateral sinus externally—the ink-line showing meeting-point.

of the parts has taken place. There is no superficial guide as to whether the cavity is large or small,

FIG. 66.

Posterior aspect of preceding specimen, the ink-line showing outline of the posterior antral wall.

but if, while opening it, the outer wall is found to be dense, the cavity is usually small.

(2) *The walls.*—(i) The outer has been considered.

(ii) The inner is usually finely cellular above and behind the external semicircular canal.

(iii) The posterior varies greatly: the antrum may be so small that a posterior wall cannot be dis-

FIG. 67.—ADULT.

Left bone. Showing thin posterior antral wall devoid of cells and roughly triangular in shape. The cerebellum lies against it.

tinguished, or the wall may be separated from the posterior fossa by such dense bone as to preclude infection passing through. A well-formed posterior wall, roughly triangular in shape, may be composed of thin, translucent bone against which may lie the cerebellum alone, the cerebellum and lateral sinus, or the sinus alone. Often it is cellular with a thin outer compact layer.

It is an important point to note that a dense outer antral wall may be associated with an extremely thin posterior wall, inviting extension of suppuration to the posterior fossa.

FIG. 68.

Posterior surface of preceding specimen, the ink-mark showing the outline of the posterior antral wall.

(iv) The roof remains for the most part very thin, and is often lined with fine cells. It may even have gaps in it, bringing the dura mater in contact with the lining membrane. Very rarely it is dense. The projection from the under surface formed by the free edge of the squama at the petro-squamosal suture is often quite thick, dividing the roof into an inner and an outer part, both of which may be lined with cells which are sometimes connected with the ridge by thin spicules of bone. The ridge always

requires removal during the radical operation in order thoroughly to inspect and clean the parts internal to it.

FIG. 69.—ADULT.

Left bone. Showing ridge in roof of antrum formed by the inner projection of the squama at the petro-squamosal suture.

E. VARIATIONS IN THE MIDDLE EAR

(1) RECESSES AND CELLS

The recesses and cells in the middle ear are of importance in forming receptacles for diseased lining membrane and purulent debris, and so being responsible for the continuation of discharge from the cavity even after the performance of the radical operation.

(i) *Recesses.*—The fossa on each side of the pyramid varies greatly.

(*a*) The outer may run backwards outside the facial nerve and almost, if not quite,

come into relationship with the upper mastoid cells.

(*b*) The inner or sinus tympani, is often of comparatively great extent running backwards with the canal for the stapedius and facial nerve immediately external to it, and the outer wall of the vestibule internally. It may dip down forming a pocket,

FIG. 70.—TWENTY YEARS.

Showing deep elongated sinus tympani running inside the facial nerve and reaching the outer wall of the vestibule. The parts outlined in ink.

and having the sulcus jugularis as an inner wall below the vestibule, or the sulcus may form a thin sloping floor to it. As I have stated before, in some cases it is absolutely impossible to enlarge the cavity or even to clean it instrumentally without destroying the facial nerve.

FIG. 71.—ADULT.

Left bone. Showing a deep sinus tympani from behind. It has a small opening above and dips down, coming into close relationship with the outer wall of the sulcus jugularis. Sinus outlined in ink.

(*c*) A recess or cell is occasionally seen in front of the head of the malleus and above the canal for the

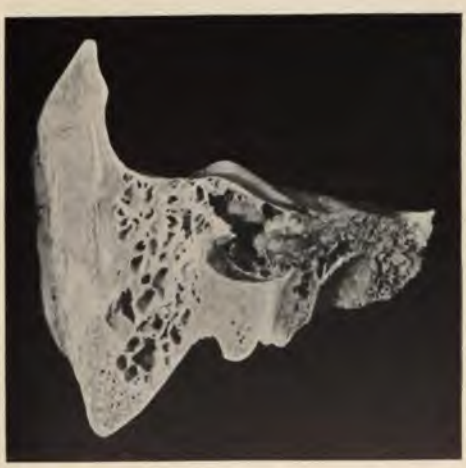

FIG. 72.—ADULT.

Right bone. Showing a small triangular pocket on inner middle-ear wall, immediately above canal, for tensor tympani and in front of head of malleus.

tensor tympani. The facial nerve lies against its inner wall.

(ii) *Cells.*—(*a*) From the hiatus Fallopii a series of cells sometimes pass forwards and inwards above and internal to the canal for the tensor tympani and, running over the carotid canal, reach the internal diploe.

FIG. 73.—ADULT.

Right bone. Showing cells from floor and top of inner middle-ear walls running inwards over the carotid canal to reach the internal diploe. A distinct line separates the two sets. The upper set starts from the hiatus Fallopii.

(*b*) The cells which line the floor sometimes also extend over the carotid canal and reach the internal diploe; passing in front of the inner part of the cochlea they separate it from the canal.

FIG. 74.—ADULT.

Right bone. Showing cells lining the floor of the middle ear extending under the labyrinth.

Occasionally they exist together with the cells from the hiatus, running parallel to and underneath them (*see* Fig. 73).

(*c*) The floor cells may extend inwards, well under the labyrinth, and forwards into the floor of the bony Eustachian tube.

(2) VARIATIONS IN THE FLOOR

The floor may remain very thin and translucent as in the infant; it may even bulge upwards, when it would be just possible by gross carelessness to wound the jugular bulb while incising the membrane. On the other hand, it may be thick and composed of dense bone.

FIG. 75.—ADULT.

Right bone. Showing thin middle-ear floor formed by a high outpushing sulcus jugularis.

FIG. 76.—ADULT.

Right bone. Showing dense middle-ear floor ¼ in. in thickness.

The mastoid cells may extend under the floor at its posterior part on their way to reach the internal diploe.

FIG. 77.—THIRTY-EIGHT YEARS.

Right bone. Showing mastoid cells extending under the back part of the middle-ear floor and vestibule.

LECTURE III

A. THE SURGICAL IMPORTANCE OF THE ANTRUM

THE antrum, whatever its physiological function may be, is a veritable death-trap when it becomes infected. The drainage from it into the lower middle ear is necessarily very imperfect, owing to the facts that its lower part is usually on a lower level than its opening into the attic, and that the attic is occupied by the head of the malleus, the body and posterior process of the incus, and their surrounding folds of mucous membrane.

It will be remembered that the antrum has a roof through which the meninges of the middle fossa and the temporo-sphenoidal lobe may be infected, an inner wall through which the semicircular canals and vestibule may be attacked, a posterior wall leading to the meninges of the posterior fossa and to the cerebellum and lateral sinus, and an apex opening into the mastoid cells with their numerous extensions when they exist.

Infection takes place through the middle ear, either by way of the Eustachian tube or of the

meatus. Direct infection of the cavity due to injury is exceedingly rare.

In fracture of the base of the skull involving the temporal bone, the line of fracture usually runs along the roof of the attic and antrum external to the dense labyrinth, the line of least resistance, practically separating the squamous portion from the petrous.

FIG. 78.—CHILD.

Left bone. The outer antral and posterior-superior meatal walls and most of the outer attic wall removed. The head of the malleus and body of the incus are seen in the attic. The membrane is intact.

The dura mater is liable to be torn along the line of fracture, the tearing taking place at the petro-squamosal suture which lodges a process of dura mater.

In cases of acute suppuration the cavity may act as a reservoir necessitating opening before healing

will take place. If the opening be too long delayed, or if the infection be very virulent as in influenza or scarlet fever, the lining membrane is destroyed, and the bony walls are attacked leading to perforation or extension to either fossa and its contents; the mastoid cells, if they are present, may be implicated with tracking of pus in any of the directions described.

It will be apparent from the description of the cells which has been given, how great an influence the anatomical condition must have in deciding the direction in which suppuration may spread.

Infection of the meninges, brain, or lateral sinus may take place through the emerging veins or their perivascular coverings, and, therefore, without macroscopical evidence of the pathway taken.

All these complications may take place even without rupture of the membrane.

As a rule, in acute cases, when the antrum alone is infected, removal of the outer wall is sufficient to produce healing, without touching the middle ear. While if the mastoid cells are also involved thorough opening of them alone is sufficient, care being taken that the opening from the lower part of the antrum into the mastoid wound is large and allows of free drainage.

There are some acute cases, however, especially in those due to scarlet fever, in which the destruction of parts is so rapid and extensive that the radical operation is necessary.

In chronic suppuration, there are usually found

gross changes in the middle-ear tract which cause the persistence of discharge. These lesions may be: chronic changes in the lining membrane, destruction of the lining membrane with caries of some part of the bony walls or ossicles with the formation of granulation tissue, and the collection of inspissated pus or cholesteatoma. Apart from these local troubles, the mastoid cells may be affected with all their attendant dangerous conditions, or the middle and posterior fossæ and their contents may be attacked.

Under these circumstances the radical operation is performed, and by it all the cavities are laid open into one another and into the bony meatus.

In all cases of intra-cranial complications the radical operation should first be undertaken, for not only is the starting-point thus dealt with, but, as the precise diagnosis of intra-cranial complication is often difficult or impossible, careful examination of the exposed walls will, as a rule, give the clue to the direction or directions in which the infection has spread, and the bone wound can then be enlarged in the necessary direction or directions, and the pathological pathway obliterated.

In dealing with cases of chronic suppuration we have yet to learn whether the opsonin treatment introduced by Professor Wright will help us.

Besides the ordinary pathogenic organisms the middle-ear tract may be invaded by the tubercle bacillus. This infection adopts a most insidious course, producing great destruction of the parts,

the carious process often extending to great lengths, even invading the meninges, before producing gross signs, and, as I have before stated, the process may extend through the cancellous covering of the labyrinth producing exfoliation of part or even the whole of that structure, or it may directly invade it, especially in the neighbourhood of the windows and the external semicircular canal. The onset of tubercle is usually free from pain and a discharge from the ear occurring without it should always arouse suspicion. Facial paralysis is often a somewhat early complication.

The infection may spread up the Eustachian tube and, according to some authorities, it may originate primarily in the bone itself.

I have a specimen removed from an infant in which the lining membrane was certainly the part first affected by the disease. A perforation was present in the posterior segment, and the lining membrane seen through it was thick and nodular. On cutting a section of the antral lining membrane which was macroscopically thickened, it was found to be infiltrated with tuberculous disease. In this case there was no external sign of antral involvement. It becomes a question then, when once the middle ear has been diagnosed as being the seat of tubercle, even although no gross signs are present, whether the whole tract and its contents should be removed by the radical operation or whether the case should receive the open-air treatment. Of course there are many questions, which I must

not now discuss, to be considered before deciding. Here again, Professor Wright's treatment may be of value.

In cases, apart from infection, in which the labyrinth has to be dealt with, and in the operation for dividing the auditory nerve by Wallace's route it is necessary to open the antrum by a wide radical operation as a preliminary step.

B. GUIDES TO THE ANTRUM

The cavity is opened through its outer triangular wall. In early life it is easily reached by an opening made immediately behind the posterior-superior meatal wall, the line of the zygoma marking the upper limit and the posterior-superior meatal wall and the spine, if it is present, the anterior limit. The posterior limit can be judged in the first months of life by the masto-squamosal suture, always remembering that the squama overlaps the petrous.

As the meatus forms, the posterior-zygomatic line appears stretching backwards over the meatus and marking more or less accurately the floor of the middle fossa. It will be seen that the posterior-zygomatic line does not always form the upper boundary of the bony meatus, sometimes it retains more or less its infantile form and is somewhat above it.

In the event of the posterior-zygomatic line being absent in the adult, an imaginary line drawn backwards from the zygoma will take its place.

FIG. 81.—ADULT.

Right bone. Showing high position of the antrum.

Unfortunately there is no sign on the surface of the bone to act as a warning, and a high outpushing jugular bulb, which sometimes comes to within one-half to five-eighths of an inch of the surface, may be injured during the early stage of opening the cavity if the triangle is faithfully followed.

FIG. 82.

Lateral vertical section of the preceding specimen ; showing the high antrum. The upper ink-line marks the level of the posterior-zygomatic line and the lower that of the spine. The specimen also shows a high outpushing sulcus jugularis reaching to within five-eighths of an inch of the surface and under the condition in danger of being wounded.

It is also possible to wound the facial nerve in its descending part.

FIG. 83.—FORTY-TWO YEARS.

Right bone. Showing the infantile form of mastoid; a high antrum; the descending part of the facial nerve (marked in ink); and the ridge projecting from the roof of the antrum.

The mastoid cells or a single large mastoid cell

FIG. 84.—THIRTY-THREE YEARS.

Right bone. Showing a high antrum and an infantile form of mastoid.

may be opened and be mistaken for the antral cavity, but the fact that a probe cannot be passed into the middle ear will arouse suspicion. The difficulty of the condition will be vastly increased if it is associated with a dense outer antral wall and mastoid process.

Often the antrum is only partially above the base-line and only the lower part will be opened through

FIG. 85.—FORTY-ONE YEARS.

Right bone. Showing the antrum partly above but partly below the posterior-zygomatic line.

FIG. 86.

Section of preceding bone. Showing the high antrum and cellular outer antral wall and mastoid, which has a narrow rim of diploe at the tip.

the triangle. Careful examination with a probe will tell the story. In these cases the antrum may be large.

(2) Much more rarely the dura mater will be exposed through the triangle, especially at its upper part, owing to the dipping down of the floor of the middle fossa external to the labyrinth. This may occur under several conditions, especially in hydrocephalus when the bone will be found to be thin and light.

(i) The posterior-zygomatic line and the triangle may be bulged outwards, the bone forming the latter being thin and translucent.

FIG. 87.—THIRTY YEARS.

Right bone. Showing a bulging posterior-zygomatic line below which the bone slopes downwards and inwards. The ink-line indicates the roof of the antrum below the base-line of the triangle. Condition probably due to hydrocephalus.

(ii) The middle fossa may dip down immediately external to the superior canal, in which case the base-line is altogether above the roof of the antrum.

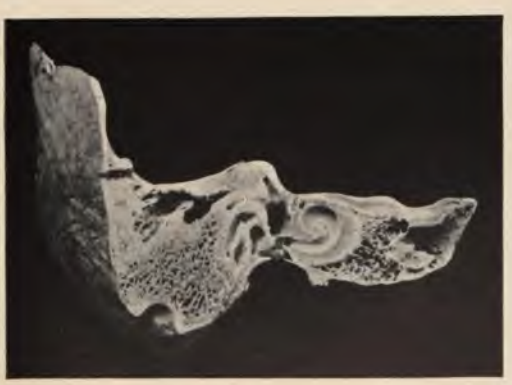

FIG. 88.—CHILD.

Right bone. Showing marked dipping down of the roof of the antrum external to the projecting superior semicircular canal. The ink-mark on the squama edge indicates the posterior-zygomatic line. Low flat antrum.

FIG. 89.—FORTY-TWO YEARS.

Right bone. Showing the posterior-zygomatic line, indicated by an ink-mark, above the level of the roof of the antrum. A large cell is present external to the antrum. The cells extend to the digastric fossa.

(iii) The middle fossa may dip down more markedly external to the antrum, in which case the base-line really corresponds to the roof of the antrum but the dura mater intervenes.

FIG. 90.—SIXTY-THREE YEARS.

Right bone. Showing marked dipping down of the middle-fossa floor external to the antrum. The ink-line on the squama edge indicates the level of the posterior-zygomatic line which really corresponds to the roof of the antrum, but the dura mater and brain intervenes between the outer antral wall and the surface.

The roof of the meatus usually shares in the depression and is often extremely thin.

In some instances the dipping down shuts out the back part of the antrum, leaving the anterior part in the triangle.

(3) Sometimes, as we have seen, the lateral sinus encroaches on the outer wall and apex of the triangle.

D. PRECAUTIONS IN OPENING THE ANTRUM

In the great majority of cases, Macewen's triangle will guide us to the front part of the antrum and its opening into the attic, when examination with a probe will tell us the extent of the cavity,

or the triangle may expose the whole of a small antrum. But we see that the antrum may be wholly or in part above the base-line, that the middle fossa may dip down, and that the lateral sinus may come up to the posterior line and even encroach upon it, or lie immediately below its apex; all these variations are without any surface condition to arouse suspicion. The spine, again, may be nowhere near the apex of the cavity or it may be absent. Under these circumstances the commencement of the opening of the antrum must be performed as if these variations were expected.

Before beginning to open the bone the upper and posterior meatal walls right down to the membrane should be exposed.

The opening should be commenced in the triangle, and the surrounding bone carefully removed as the wound is deepened forwards and inwards parallel to the meatus. If the cavity is not reached at the depth of about one-half to five-eighths of an inch—the average depth—the wound should be extended upwards and forwards working down the superior and the posterior-superior meatal walls until the opening into the attic is exposed, when a bent probe will indicate the extent to and the direction in which to enlarge the wound so as to expose the antrum.

If the dura mater of the middle or posterior fossa be exposed in doing this, it may be used as a guide.

Although exposure of the dura mater does no harm, yet perforation may be fatal if the operation

is performed for septic disease. Accidental opening of the sinus *may* do no harm, but it is a handicap to the thorough performance of the operation.

E. THE RADICAL OPERATION

This operation consists in removing the whole outer wall of the antrum; laying the cavity open into the middle ear by a wide removal of the posterior meatal and outer attic walls; removal of the membrane, malleus, and incus; and in the cleaning out of all diseased contents and bony walls. It may also involve the tracking of disease to its finality in any direction, and the obliteration of the diseased pathway.

The operation is commonly known as the radical "mastoid" operation, but, unless the disease is very extensive, it takes place almost entirely through the squama.

F. THE FACIAL NERVE IN THE ADULT ESPECIALLY IN REFERENCE TO THE RADICAL OPERATION

It has been stated that the facial nerve does not alter its position during growth, but there is an increase of about a quarter of an inch in the descending part owing to the growth downwards of the surrounding bone.

The stylo-mastoid foramen, its point of exit, is in the line of the posterior meatal wall when looked

at from the side; from in front, it is rarely seen outside the line of the outer edge of the anterior bony meatal wall, although it is so before the meatus is fully grown. In a horizontal plane, it is situated at the lower limit of the non-projecting part of the

FIG. 91.—ADULT

Right bone. Showing the descending course of the facial nerve with a slight inclination outwards. The sulcus jugularis is just internal to the nerve.

mastoid process which closely corresponds to or is slightly above the point at which the inferior edge of the thick tympanic plate actually joins the anterior surface of the mastoid process.

In this descending course of the nerve from the external canal to the stylo-mastoid foramen there is usually a slight inclination downwards, but it may run straight downwards or even curve inwards with a final slight outward inclination (*see* Fig. 94).

A very high and outpushing sulcus jugularis may reach the inner aspect of the descending part of nerve, which indeed may be exposed in its outer wall or be separated by a very thin translucent partition (*see* Fig. 91).

FIG. 92.—SIXTY-TWO YEARS.
Right bone. Showing the course of the facial nerve.

An increase in depth also takes place as the upper part of the mastoid process grows outwards. This increase varies to such a degree that measurements are worse than useless.

The nerve may be separated from the mastoid cells by dense bone or the cells may come right up to it, a dangerous spot being just after it has left the shelter of the external canal (*see* Fig. 93).

FIG. 93.—TWENTY-FOUR YEARS.
Right bone. Showing straight descending course of the facial. The mastoid cellular.

During the radical operation the nerve may be injured in its descending course before the antrum

FIG. 94.—ADULT.
Right bone. Showing the descending course of the nerve curving inward, reaching the sulcus jugularis and then recurving outward.

is opened, especially if the cavity is small and highly placed, a facial twitch or complete paralysis being,

perhaps, the first sign that something is wrong. Avoidance of the nerve, at this stage, is effected by keeping the bone wound high up, especially if the antrum is not reached at about half an inch.

FIG. 95.—FORTY-EIGHT YEARS.

Right bone. Showing relation of the descending part of the nerve to the surface in a specimen in which the antrum is high. The nerve is in danger during the opening of the antrum. The ink-mark indicates the level of the posterior-zygomatic line.

If a guide such as Stacke's is used through the meatus for ascertaining and marking the position of the opening of the antrum into the attic it may injure the nerve if used roughly, especially if the facial canal is open ; it may pass into a deep sinus tympani causing the operator to think that the external canal and the facial nerve are the outer boundaries of the antral opening, or the operator may be tempted to use it as a lever, with the external

canal and the facial nerve as a fulcrum, in removing the last part of the outer attic wall. It is better, on the whole, not to use such an instrument, although it is safe enough in an experienced hand, when it is not wanted.

In removing the last part of the "bridge" in

FIG. 96.—FIVE AND A HALF YEARS.

Left bone. The middle ear is exposed, and part of the outer antral wall removed, showing the "bridge" to be removed in laying the antrum into the middle ear and meatus, and the relationship of the facial nerve to the operation. The descending part of the nerve is laid open.

order to lay the antrum open into the middle ear, the nerve, as it crosses the inner wall of the middle ear, is in danger. It is avoided by having the parts well exposed, cleared from blood and lighted, by keeping high up and by defining the amount of bone to be removed by means of a probe passed into the middle ear from the antrum. A small piece of sponge or gauze may also be packed under the part which is to be removed.

In curetting the upper and posterior middle-ear walls injury may occur, especially if rough attempts are made to clean the sinus tympani or any attempt is made to enlarge its opening. Curetting should be performed with a very light hand and, as far as is possible, in the direction of the course of the nerve. If there is a gap in the canal the danger of injury is increased and temporary paralysis may follow even the most careful curetting.

In removing the posterior meatal wall the descending part of the nerve is again in danger below the external canal. The best guide for avoiding it at this stage is that originated by Hugh Jones of Liverpool.

After the antrum has been laid into the middle ear and the external canal exposed, a line drawn from the outermost part of the canal to the highest point of the meatus will have the nerve internal to it; with the exception of the bone internal to Jones's line the posterior meatal wall may be levelled to the floor of the meatus.

FIG. 97.—ADULT.

Right bone. The anterior wall of the meatus has been removed, showing the radical operation and the relation of the facial to it. The specimen illustrates Hugh Jones's guide for the prevention of injury to the nerve when removing the posterior meatal wall—viz., a line drawn from the external semicircular canal to the highest part of the floor of the bony meatus will always have the nerve internal to it. The line and the nerve are marked in ink.

Another point in curetting the middle ear is to avoid dislocating the stapes, which is easily done if the curette catches in the projecting head of the bone. The stapedius tendon is pulled upon and the base of the bone is levered out of the oval window. Temporary instability may be produced and the hearing result is not so good.

G. THE PETRO-SQUAMOSAL SINUS

In early fœtal life, before the formation of the internal jugular vein, the petro-squamosal sinuses

carry away all the intra-cranial blood, passing along the roof of the antrum and middle ear in the course of the petro-squamous suture and emerging at an opening in front of the meatus. It is not surprising that remains of such an important structure are seen later in life. In infancy and early childhood it is sometimes in evidence grooving and canalising the bone in the immediate course of the suture, lying partly under the overlapping tegmen, and emerging in front of the meatus.

FIG. 98.—THREE YEARS.

Left bone. Showing deep groove for the petro-squamosal sinus.

FIG. 99.—THREE YEARS.

External aspect of the preceding specimen. Showing the opening between an unusually large post-glenoid tubercle and the meatus, with a groove running outwards. This is a very rare specimen. Professor Macewen figures a similar one in his book from a ten-days-old infant.

But it may be present without these gross signs. It often opens posteriorly into the lateral sinus, below and external to the superior petrosal by a valve-like opening, sometimes passing under a bridge of bone to do so.

FIG. 100.—FIVE YEARS.

Right bone. Showing the valve-like opening of the petro-squamosal sinus into the lateral sinus.

The external opening is often obliterated, but remains may often be seen in the usual position in front of the meatus just external to the Glaserian fissure, with sometimes a fine groove running outwards and occasionally bridged over by the junction of the post-glenoid tubercle with the bony meatus, in the glenoid cavity, in the zygomatic process or in the base of the zygoma. In its passage it receives

FIG. 101.—ADULT.

Showing the superior surface. The dura mater is thrown back to show groove for sinus which lies in the dura mater.

veins from the middle ear which have a covering from the meninges, one especially being present about the level of the meatus. It also receives veins from the meninges and the adjacent temporo-sphenoidal lobe above.

FIG. 102.

The outer surface of the preceding bone. Showing perforation in the zygoma.

FIG. 103.

Posterior surface of the same. Showing the opening under a bony bridge into the sigmoid groove.

The surgical importance of this sinus and its remains consists in the intimate connection of the middle ear with the meninges by means of the perivascular covering, especially in infancy when the suture is wide and unclosed. It is not infrequent

FIG. 104.—ADULT.

Left bone. Showing the superior surface. The dura mater is thrown back, showing partly bridged-over groove. The sinus is seen in the turned-back part. There is a wire passed through the anterior opening, which apparently is going to perforate the zygoma.

for infants to die of general meningitis during an attack of acute otitis, and I have specimens in which this has occurred without the membrane having given way. It explains also the formation of an

FIG. 105.

Section through front of preceding specimen. Showing canal in the zygoma.

FIG. 106.

Posterior aspect of same. Showing the opening of the sinus into the lateral sinus.

abscess in the temporo-sphenoidal lobe in those cases in which there is no macroscopical evidence of the pathway of infection.

Occasionally it is the pathway for septic thrombosis of the lateral sinus. Cleveland of Philadelphia

FIG. 107.—ADULT.

Left bone. Showing a deep partly bridged-over groove opening into sigmoid groove under bridge; no anterior opening.

recorded such a case in a boy aged six who died of pyæmia. At the post-mortem the sinus was found abnormally large and deep, being at one or two points almost entirely bridged over by bony processes. At its anterior extremity necrosis had

taken place and pus had entered the sinus, causing a thrombus which extended backwards into the lateral sinus. Meningitis was present on the same side.

In St. George's Hospital Museum (No. 33a) is a specimen of dura mater with the lateral and longitudinal sinuses from a man aged twenty who, after

FIG. 108.—ADULT.

Left bone. Showing shallow groove partly bridged-over opening into sigmoid groove; no anterior opening.

suffering with discharge from the right ear for three months, died with symptoms of meningitis. At the post-mortem examination suppurative meningitis was found over the right side with septic thrombosis of the lateral and longitudinal sinuses. A vein was found which made a direct communication between the tympanum and the lateral sinus,

and which would admit the passage of an eye probe.

A large sinus may be encountered in exploring the middle fossa, or in Parry's operation for dividing the facial nerve by the middle fossa route.

H. RELATIONS OF THE SULCUS JUGULARIS

The sulcus, against which lies the jugular bulb,

FIG. 109.—SEVENTY-TWO YEARS.

Right bone. Showing a high and outpushing sulcus jugularis with the facial nerve running through its outer wall. The sulcus reaches to half an inch of the surface.

stretches right across the width of the inferior surface of the bone internal to the articulating surface for the occipital bone, the stylo-mastoid foramen and the styloid process, and external to the aqueductus cochleæ and the internal carotid canal.

It forms, I beg to repeat, externally, the thin perforated floor of the middle ear. Internally and

anteriorly it lies against the inferior surface of the beginning of the first turn of the cochlea. Internally and posteriorly it lies against the inferior surface of the inferior limb of the posterior semicircular canal as it enters the floor of the vestibule.

During growth the sulcus may become separated

FIG. 110.

Section further back in preceding specimen. The sulcus lying against the inferior surface of the inferior crus of the posterior semicircular canal as it enters the vestibule and also against the floor of the internal auditory meatus.

from these structures by about a quarter of an inch of dense bone, or the mastoid cells may extend under it. Often, however, the sulcus not only retains its infantile condition, but also pushes upwards and outwards, rendering the floor of the middle ear and sinus tympani exceedingly thin and even

causing a marked upward bulge in the floor of the middle ear, when it would be possible by gross carelessness to injure it while incising the membrane.

It may remain lying against the inferior limb of the posterior canal and the floor of the internal auditory meatus.

It may reach the facial nerve in its descending

FIG. 111.

Posterior aspect of the same ; the ink-mark showing the outline of the sulcus, which reaches nearly to the border above and the lateral sinus externally.

course, and the nerve may even run through the outer wall. Behind the nerve it may come into the closest relationship with the upper mastoid cells and their extensions inwards above and below it, and it may come to within half an inch of the surface.

On the posterior aspect of the bone it may be seen to bulge upwards and outwards reaching as high as

the border separating the superior and posterior surfaces and as far out as the groove for the lateral sinus running under the aqueductus vestibuli and saccus endolymphaticus; it would be in danger at this point in Wallace's operation for division of the auditory nerve when the bone is being removed internal to the lateral sinus groove.

I. DIVISION OF THE AUDITORY NERVE

The auditory nerve has been divided at the internal auditory meatus for distressing tinnitus and giddiness, as an alternative operation to that of Lake, but the operation is still *sub judice*, and although in the few cases recorded the operation has not met with much success, yet the time may come when, by choosing the right cases and by the adoption of more perfect procedures, it will have its proper place in surgery. Negative results are sometimes of the greatest value, helping to clear up matters which otherwise would remain dark.

One would think that division of the auditory nerve would have some effect on tinnitus and labyrinthine vertigo, as the pathway from a diseased aural apparatus is thus at once interrupted; but if there is no effect, we are driven to the conclusion that the symptoms have their origin in some other part, probably central, to which we must direct our attention if these difficult cases are to be relieved.

It is a curious thing that cerebral tumours which press on the auditory nerve in its intra-cranial course

do not cause tinnitus, at any rate it is not complained of as one would expect. It seems that it is necessary for the nerve ending in the cochlea to be irritated in order to produce it.

The operation of division of the eighth nerve originated with British surgeons, and cases have

FIG. 112.—TWENTY YEARS.
Left bone. Showing the posterior surface.

been reported by Cuthbert Wallace, *Lancet*, April 30, 1904,—and R. H. Parry of Edinburgh, "Transactions of the Otological Society," vol. v. 1905, page 62, and they each adopted a different route. Cuthbert Wallace in his description gives two routes by which the nerve can be reached :—

(i) By exposing the cerebellum in the usual way, opening the dura mater and slowly compressing the cerebellum inwards until the facial and auditory

nerves come into view; and (ii) by the operation for exploration of the posterior surface of the petrous portion, after a wide radical operation has been performed.

He chose this second route, as the radical operation had already been performed.

The steps of the operation by this second route he describes as follows:—

(1) The radical operation is widely performed, and the lateral sinus exposed.

(2) The dura mater over the temporo-sphenoidal lobe is exposed, and by working backwards and downwards the dura mater over the cerebellum, for a distance of three-quarters of an inch behind the lateral sinus, is laid bare in order to gain space for the retraction of the cerebellum in the later stage.

(3) The bone internal to the lateral sinus is next removed, starting from the groove and extending forwards and inwards as far as the external semicircular canal; this exposes the dura mater, for a space of three-eighths of an inch in width on the average, internal to the sinus.

(4) The anterior edge of the exposed dura mater is then incised to the extent of about one inch.

(5) A bent flat half-inch broad retractor is then introduced and the cerebellum compressed until, with the aid of a forehead light, the auditory nerve can be seen running obliquely into the meatus.

(6) Pressure on the auditory nerve applied as near the brain as possible enables the facial to be brought into view, and a blunt hook can then be

easily passed round the auditory nerve which is divided by traction or with scissors.

He states that the depth of the nerve from the cut edge of the petrous varies from one half to three-quarters of an inch.

In the case in which he operated through this route, bleeding from the lateral sinus, before the dura was opened, necessitated plugging and the postponement of the further steps. A week later the operation was proceeded with. On opening the dura a large amount of cerebro-spinal fluid at once flowed out. On introducing the retractor it was found that the clotted sinus caused resistance to retraction, it was therefore divided between ligatures. After considerable trouble from the flow of cerebro-spinal fluid and bleeding from the surface of the cerebellum the nerve was seen and torn in half. As a result the tinnitus from which the patient suffered was certainly relieved but there was considerable giddiness on attempting to raise the head. Unfortunately the patient died, so that the chief interest in the case is the route adopted and the troubles encountered.

Parry divided the nerve in a man for incapacitating vertigo and tinnitus.

He operated through the middle fossa; the points in favour of this route being that: (i) less difficulty was anticipated as regards hæmorrhage; (ii) it is the shortest route, the internal auditory meatus being one inch and a quarter from the squama; and (iii) the parts can be better retracted.

The steps of the operation were :

(1) An osteo-cutaneous flap was turned down from the squama.

(2) The dura mater was separated with great care from the superior surface of the petrous as far as the promontory caused by the superior semicircular canal.

The roof of the middle ear and part of the antrum were removed at this point (more I think to explore the tract than as a necessary part of the operation—and it certainly added an extra risk for there had been suppuration in the middle ear).

(3) The dura mater was punctured to allow of the escape of cerebro-spinal fluid, and so permit the better displacement of the membrane and brain.

(4) The superior petrosal sinus was removed by chiselling the groove and gently removing the bone in order to avoid puncturing the sinus, for as Parry states, the sinus lies in a marked groove along the whole length of the border in half the bones he examined.

(5) The dura mater of the middle fossa, the tentorium and the superior petrosal sinus were drawn aside by retractors. Some bleeding occurred at this stage, probably from the sinus, but was easily controlled by plugging.

(6) The roof of the meatus was then removed when the seventh and eighth nerves were easily recognised. A little too much of the roof was removed and the seventh nerve was injured.

(7) The auditory nerve was divided.

Recovery was uneventful, but the vertigo and tinnitus, though modified somewhat, were still sufficiently in evidence to annoy the patient.

From the records of these two cases, the operation of Parry seems to be the easier and open to less objection than that of Wallace.

In Wallace's route the variation in the position of the lateral sinus, which is easily wounded, is a distinct disadvantage.

In some cases it is impossible to obtain any room internal to the sinus to incise the dura, and in all the opening is necessarily small.

The bleeding from the surface of the cerebellum and the cerebro-spinal flow appear to be inevitable.

The antrum has always to be opened, an operation which is sometimes tedious and may be a source of infection.

In Parry's route the bone opening can accord plenty of room. The antrum need not be opened, and the bleeding need not be violent; the only large sinuses encountered are:—the petro-squamosal, if it is present, and the superior petrosal, both of which can be easily controlled without postponing the operation. The puncturing of the dura, to let out cerebro-spinal fluid, could with advantage be replaced by a lumbar puncture. A difficulty may arise, as we have seen, in determining which is the projection of the superior canal.

Removing the roof of the internal auditory meatus should be carried out along the border of the bone in order to avoid the facial nerve.

J. VARIATIONS IN THE MASTOID VEIN

This vein leaves the lateral sinus in its descending part and usually runs upwards, backwards and outwards with a curved course, to emerge at the posterior edge of the base of the mastoid process.

There may be more than one, or one vein may branch in the bone into two or more branches which emerge separately on the outer surface.

Great variations are seen in its size, sometimes it is as big as a pencil, at others the canal will not admit a pin, and in some it is absent altogether.

The point of emergence varies, it may be situated quite low down behind the mastoid process.

In cases of septic thrombosis of the lateral sinus this vein sometimes shares in the process and requires dealing with. Sometimes an abscess will form round its point of emergence, and its bony canal may be carious.

Under these circumstances the vein must be removed up to its origin from the sinus by enlarging the canal and laying it open into the bony wound.

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